

element, and an essentially planar support. The principal element combines the functions of elastic energy storage and one capacitor plate, and may be as simple as a plane rectangle of thin spring metal. As described in more detail below, the sensor may be implemented with a small number of mechanical parts and a very small capacitive gap, making the sensor easy and inexpensive to manufacture and making the sensor particularly applicable for use in mobile and handheld devices. It should be stressed, however, that sensors made in accordance with the invention may be of great advantage in a wide range of devices, sizes, and applications. To date, they have been successfully used in devices with a working diagonal of from 4" to 15", and supported touch surface assemblies weighing from 0.6 ounces to nearly 4 pounds.

[0020] For example, in one aspect of the invention, a force sensor for sensing a touch force applied to a touch surface is provided. The force sensor comprises: a first element including an elastic element and a first capacitor plate having a first capacitive surface, the elastic element including at least part of the first capacitor plate; and a second element including a second capacitor plate opposed to the first capacitor plate; wherein transmission of at least part of the touch force through the elastic element contributes to a change in capacitance between the first capacitor plate and the second capacitor plate. Various other force sensors are also provided, as described in more detail below.

[0021] In yet another aspect of the invention, a force sensing touch location device is provided. The force sensing touch location device comprises: a touch surface; a bezel enclosing a first portion of the touch surface; and force transmission means including an enclosing portion enclosing a second portion of the touch surface, said force transmission means having a stiffness greater than that of the bezel, wherein the force transmission means includes a path to transmit force from the bezel to a region not including the touch surface.

[0022] In a further aspect of the invention, a force sensing touch location device is provided. The force sensing touch location device comprises: a touch surface defining a touch plane; a first rigid member; a contoured first film coupled to the touch surface and the first rigid member to form a first seal therebetween, the contoured first film being compliant along an axis normal to the touch plane.

[0023] In another aspect of the invention, a method is provided for measuring a touch force applied to a touch surface using one of the force sensors described herein. The method comprises a step of developing a signal based on the change in capacitance between the first capacitor plate and the second capacitor plate of the force sensor. The amplitude of the signal may be a monotonic function of the change in capacitance between the first capacitor plate and the second capacitor plate. The method may include a step of measuring a property of the touch force, such as the amplitude of a component of the touch force that is perpendicular to the touch surface, based on the signal. **85.** The method may include a step of measuring a location on the touch surface at which the touch force is applied.

[0024] In yet another aspect of the invention, a method is provided for separating a first capacitor plate from a second capacitor plate in a force sensor by a desired volume. The method comprises steps of: disposing a separator between a

support surface and a principal element including the first capacitor plate to maintain a separation of at least the desired volume between the first capacitor plate and the second capacitor plate; coupling at least one region of the principal element to at least one region of the support surface; and removing the separator, whereby the first capacitor plate and the second capacitor plate remain separated by at least the desired volume in an unloaded state of the force sensor. The support surface may, for example, be the second capacitor plate.

[0025] In a further aspect of the invention, a method is provided for separating a first capacitor plate from a second capacitor plate in a force sensor by a desired volume. The method comprises steps of: disposing a predetermined substrate containing particles of controlled size between a support surface and a principal element including the first capacitor plate to produce a separation of at least the desired volume between the first capacitor plate and the second capacitor plate; and coupling at least one region of the principal element to at least one region of the support surface to maintain the separation of at least the desired volume between the first capacitor plate and the second capacitor plate.

[0026] In another aspect of the invention, a method for manufacturing a force sensor is provided. The method comprises steps of: selecting a principle element including a substantially flat surface and a first capacitive surface; disposing the first capacitive surface in opposition to a second capacitive surface; and forming an elevated elastic feature into the substantially flat surface, whereby transmission of a force through the elevated elastic feature contributes to a change in capacitance between the first capacitor plate and the second capacitor plate.

[0027] In another aspect of the invention, a force sensing touch location device is provided. The force sensing touch location device comprises: a touch surface structure to which a touch force may be applied, the touch force including a perpendicular component that is perpendicular to a touch surface of the touch surface structure and a tangential component that is tangential to the touch surface of the touch surface structure; a supporting structure; at least one force sensor, in communication with the touch surface and the supporting structure, to measure properties of the touch force; lateral restraint means, in contact with both the touch surface structure and the supporting structure, for impeding lateral motion of the touch surface structure without substantially impeding transmission of the perpendicular component of the touch force through the at least one force sensor.

[0028] Other features and advantages of various embodiments of the present invention will become apparent from the following description and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] **FIG. 1A** is an exploded drawing of a touch screen module of a first preferred embodiment, as might be used against the face of a separate LCD module.

[0030] **FIG. 1B** is a partial cross-section of the module of **FIG. 1A**, intersecting the center of a sensor.

[0031] **FIG. 2** is a cross sectional view of a first embodiment, in a typical application installation.